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DRAWINGS ATTACHED

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(54) TACHOMETER

(71) We, UNITED AIRCRAFT CORPORATION, a corporation organised and existing under the laws of the State of Delaware, United States of America, of 400 Main Street, East Hartford, Connecticut, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to tachometers. The tachometer described is especially suitable for use in association with jet engines.

The invention comprises a rotary machine having at least one conductive non-magnetic member located at a point not on the axis of said machine, said machine comprising a tachometer for producing a signal representing the speed of said machine including a magnetic circuit having an air gap located in such a way that said member passes through said air gap during operation of the machine, means for producing a static magnetic flux in said circuit and means responsive to reduction in said flux produced by eddy currents generated in said member as it passes through said air gap for producing said signal.

Preferred features and advantages of the invention will become apparent from the following description of an embodiment thereof, given by way of example, in conjunction with the accompanying drawings in which:

FIGURE 1 is a schematic view of a tachometer, according to an embodiment of the invention.

FIGURE 2 is a diagram illustrating the output produced by the tachometer.

Referring now to the Figure 1, the tachometer indicated generally by the reference character 10 is illustrated in use in connection with the compressor section of an aircraft jet engine. Only fragments of a few of the compressor blades 12 are shown, it being understood that the compressor actually has a multiplicity of such blades 12. A shroud 14 surrounds the blades 12. The shroud 14 is provided with an opening 16 in which is mounted a housing 18 formed of magnetic material. Bolts or screws 20 attach a flange 22 on housing 18 to the shroud 14.

The tachometer 10 includes a core 24, formed of magnetic material, which is secured to the closed end 26 of housing 18 by any suitable means such as by welding. The end of core 24 remote from the closed housing end 26 carries a permanent magnet 28 disposed adjacent the open end 30 of the housing 18. In the structure just described, it will be seen that there is provided a magnetic circuit including the wall of the housing 18, the core 24, the permanent magnet 28 and the relatively large air gap between the permanent magnet 28 and the open end 30 of the housing. The flux Ø generated by magnet 28 is illustrated by broken lines in FIGURE 1.

The blades 12 are formed of conductive, non-magnetic material. As the blades 12 move through the flux Ø in the air gap of the device, eddy currents are generated in the blades. These eddy currents in turn produce flux which opposes the flux which caused the eddy currents. Owing to the arrangement of the air gap and the consequent flux path, as a blade passes through the air gap, the flux in the magnetic circuit passes through a complete cycle of variations.

A coil 32 is mounted on the core 24. Coil 32 is so wound that the axis thereof is coaxial with core 24. As the flux in the magnetic circuit passes through a cycle of variations, lines of force cut the turns of the coil 32 to cause a voltage to be induced therein. The voltage induced in the coil 32 in response to the passage of successive blades 12 through the air gap flux is illustrated in FIGURE 2. It will be seen that as each blade passes through the gap the voltage induced in the coil goes through one cycle of variation. Moreover, the distance between corresponding points in two successive cycles of variation is a measure of

the time between the passage of the first blade past the tachometer and the time of passage of the next succeeding blade past the tachometer. This time, in turn, is a measure of the rotational speed of the compressor.

One advantage of the tachometer described over a conventional magnetic pick-up is that it produces a relatively large output signal even when the air gap, or space between a blade tip and the sensor, is relatively large. For example, typical spacing in a conventional tachometer pick-up for sensing ferrous blades is 0.005 inch to 0.020 inch. The sensor described on the other hand, will operate with an air gap up to 0.50 inch, though a smaller gap will give a proportionately larger output. The signal-to-noise ratio of the sensor is better than 10: 1 even when a relatively large air gap is used. Usable outputs have been obtained at blade speeds of less than 20 feet per second and up to 450 feet per second.

In one particular installation wherein the tachometer was used in connection with a 93 inch diameter compressor fan having forty-six non-ferrous blades with a normal spacing of 0.200 inch between the blade tip and the magnet 28, the tachometer provided a useful output from about 120 rpm to about 4,000 rpm. With forty-six blades at 120 rpm, voltage at ninety-two cycles per second was generated in the coil 32. At 4,000 rpm, there were voltages at 3,066 cycles per second induced in the coil 32. Arbitrarily a speed of 3,600 rpm was selected as that which would produce 100% scale reading on an indicator to be described. In the case of a forty-six blade compressor, the resultant output from coil 32 was 2,760 cps. The coil output was applied to the input section 36 of a counter 38 though a rectifier 40. Thus at a compressor speed of 3,600 rpm, 2,760 pulses per second were applied to the input section 36. Arbitrarily letting 100 counts represent a full scale reading, the counter 38 was re-set after each 100 counts. It will be appreciated that 100 counts are produced each 0.032 second.

An oscillator producing a signal having a frequency of 884 cps was employed and its output signal frequency divided by 32 in a dividing network 44 to produce a re-set signal every 0.032 second on a line 46. Network 44 may, for example, be made up of five flip-flops so arranged as to perform the required frequency division. The pulses on line 46 were applied directly to a gating circuit 48 to which the output of counter 48 was applied. The pulses on line 46 were applied through a delay circuit 50 to the re-set section 52 of counter 38 after a time sufficient to ensure that the counter output was read before the counter was re-set.

A storage circuit 54 to which the gate 48 applied the counter output provided one input to a comparator 56. An analogue-to-digital conveyer 58 supplied the second input to comparator 56. The comparator output was applied to a servomotor 60 which, through a linkage 62, drove an indicator 64 as well as the converter 58.

In the operation of the tachometer, a blade 12 passing through the flux Ø in the air gap between the magnet 28 and the open end 30 of the housing 18 has eddy currents generated therein. These eddy currents produce their own flux which tends to oppose the flux Ø in the gap. As a result there is a cyclic variation in the flux Ø each time a blade passes through the gap. This variation results in lines of force cutting the coil 32 to cause a voltage cycle to be introduced therein as indicated in FIGURE 2. The number of cycles per second produced in response to the passage of successive blades by the sensor is a measure of the speed of the compressor. Amplifier 34 amplifies this output, which is rectified by diode 40 and then applied to the input section 36 of counter 38.

Counter 38 counts the number of pulses and, each 0.032 second, gating circuit 48 is activated and the count passes to the storage circuit 54. Comparator 56 compares the stored count with the count of converter 58, which represents the present indication and, if a difference exists, motor 60 is energized to drive indicator 60 to indicate the new speed value. Thus, the number of pulses occurring between successive signals on conductor 46 represents the speed of the compressor, with 100 counts representing full scale or 3,600 rpm.

WHAT WE CLAIM IS:—

1. A rotary machine having at least one conductive non-magnetic member located at a point not on the axis of said machine, said machine comprising a tachometer for producing a signal representing the speed of said machine including a magnetic circuit having an air gap located in such a way that said member passes through said air gap during operating of the machine, means for producing a static magnetic flux in said circuit and means responsive to reduction in said flux produced by eddy currents generated in said member as it passes through said air gap for producing said signal.

2. A machine according to claim 1 in which said flux producing means is a permanent magnet.

3. A machine according to claim 1 or 2 in which said flux variation responsive means comprises a coil through which said static flux passes.

4. A machine according to claim 1, 2 or 3 in which said magnetic circuit comprises a housing of magnetic material, said housing having a closed end and an open end adjacent said path and a core of magnetic material extending from said closed end toward said open end.

5. A turbine including a tachometer for producing a signal representing the speed of

the shaft of said turbine, said shaft carrying a plurality of blades of conductive material, said turbine having a shroud with an opening therein including in combination, means mounted in said shroud opening providing a magnetic circuit having an air gap across which said blades pass, means providing a static magnetic flux in said circuit and means responsive to variations in said flux owing to passage of said blades through said air gap for producing said signal.

6. A turbine according to claim 5 in which said magnetic circuit comprises a housing of magnetic material supported in said shroud opening, said housing having an open end adjacent said shroud and having a closed end, and a core of magnetic material extending from said closed end toward said open end.

7. A turbine according to claim 6 in which said flux variation responsive means is a coil carried by said core.

8. A turbine according to claim 7 in which said flux producing means is a permanent magnet supported adjacent the open end of said housing.

9. A turbine according to claim 5 in which said magnetic circuit providing means comprises an elongate housing of magnetic material, said housing having an open end and a closed end, said housing open end being located within said opening, an elongate core of magnetic material, said core being carried by said closed end and extending toward said open end, said flux providing means comprising a permanent magnet carried by said core adjacent said open end, said air gap being located between the open end of said housing and said magnet, said flux variation responsive means comprising a coil carried by said core between said magnet and said closed end.

10. A machine including a tachometer, substantially as herein described with reference to the accompanying drawings.

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1226149 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

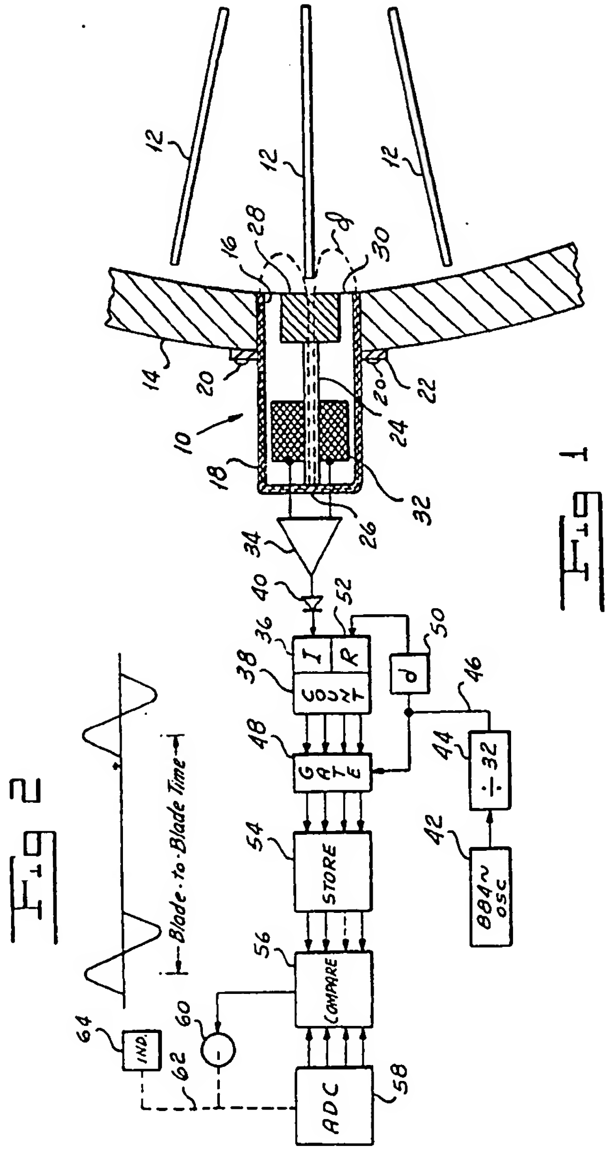

FIG. 1

FIG. 2